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SUMMER SLIDES AND WINTER SCOUR

. . . . dry - wet erosion in southern California mountains

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SUMMER SLIDES AND WINTER SCOUR--

DRY-WET EROSION IN SOUTHERN CALIFORNIA MOUNTAINS

By

H.W. Anderson, G.B. Coleman and P.J. Zinke

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ABSTRACT

To plan erosion control measures in the watersheds of southern California, we must know where the debris is coming from, how it is moved from the slopes, and something of the kinds of materials making up the debris.

This cooperative study showed that the highest rates of debris movement, by far, were from the steep front-country sites that faced south. Annual debris movement from these sites averaged 5 tons per acre of rock, soil, and organic matter. This was 5 to 10 times as much as from other sites.

During the 5-year period of study, dry-season debris movement exceeded wet-season movement on most of the sites; thus a large part of the debris movement from slopes into channels is seemingly independent of rainfall. Very little debris was flushed from the channels by the below-normal winter streamflow. Most of it still lies in the channels, a constant threat.

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SUMMER SLIDES AND WINTER SCOUR--
DRY-WET EROSION IN SOUTHERN CALIFORNIA MOUNTAINS

By H. W. Anderson, G. B. Coleman and P. J. Zinke

Along the whole Los Angeles front of the San Gabriel Mountains the "walls come tumbling down." Ton after ton of debris tumbles down from canyon walls into channels, there to be flushed out by heavy storm runoff--filling a debris basin here, choking a mammoth reservoir there, or spewing over someone's front yard in another place. Flood hazards and the costs of control measures are increased greatly by this debris. Further, debris-laden runoff is not usable and the water may be wasted to the ocean.

Where are the principal sources of this debris and under what conditions does it move down the mountain slopes? This information is needed in developing more economic and effective methods of reducing debris production at its source.

To help answer these questions, studies have been conducted by the U. S. Forest Service, with the cooperation of the Los Angeles County Flood Control District. This report summarizes some of the results of 5-years of study of debris movement down mountain slopes in the Los Angeles River Watershed. The study included measurements of the amounts of downslope movement of debris, the processes by which it moved, and the types of materials that moved down the several kinds of slopes under natural cover.

EXPERIMENTAL SITES

Six study sites were chosen. Four in the "front country" of the Arroyo Seco drainage and two in the "back country" of the Upper Tujunga drainage (fig. 1). Two of the front-country sites were chosen on rejuvenated slopes.[1/]

The other sites in both the front and back country were above the influence of rejuvenation. All experimental sites were chosen in a single geologic type--the Wilson Diorite--which is intruded with granodiorite dikes in the front country sites. The soils are characteristically shallow, sandy in texture, highly erosive, non-cohesive, and permeable. The chaparral brush cover

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1/ Rejuvenated slopes are the steep slopes flanking rejuvenated stream channels in which geologic down-cutting has been renewed by recent uplift of the fault block forming the San Gabriel Mountains.

on the sites has been long unburned, but the cover density is highly variable (table 1). The sites chosen had been undisturbed by roads or other man-caused disturbances, and were selected to sample slopes of various lengths with north and south aspects and with steep and moderate gradients above rejuvenated and non-rejuvenated channels (table 1).

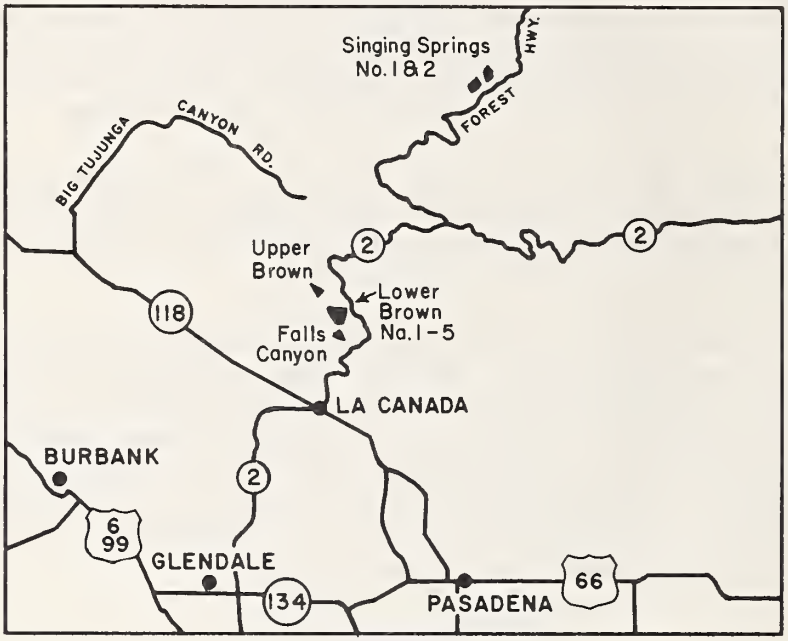

Figure 1.--Location of the study sites in the San Gabriel Mountains, California.

MEASUREMENT OF DEBRIS

Debris moving down the slopes of each experimental site was caught in a half-round steel trough. The upslope edge of the trough was connected with the original soil surface by a concrete apron (fig. 2).[2/] Wooden baffles up to 4 feet high were added at the steep rejuvenated sites to catch bouncing rocks. Generally, the trough traversed the contour from a point of a sloping ridge across a segment of a slope to end near a drainage channel. On

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2/ Design for these installations is described in: Olsen, O. C., "Work Plan for Quantitative Study of the Surface Movement of Sediments on Mountain Slopes--Los Angeles River Watershed, California." U. S. Forest Service, California Forest and Range Experiment Station. August 19, 1953, 5 pp., typewritten.

Figure 2.--Debris trough at Falls Canyon site. Material moving downslope is collected from concrete apron on uphill edge of trough and from the trough.

rejuvenated slopes, short troughs were placed across erosion chutes and debris cones.3/ Troughs ranged in lengths from 10 to 431 feet.

Material caught in each trough was removed and weighed, corrected for moisture, and sampled for organic matter and rock content. The debris was removed after major winter rainstorms and at varying intervals otherwise, but always so as to allow separation of catches for the wet and dry seasons.

RESULTS

Downslope movement of sediments varied widely between seasons and between sites, both in amounts and in kind.

PRINCIPAL SOURCES OF DEBRIS

The front-country south-facing rejuvenated slopes proved to be the principal debris producers (table 1). These slopes had average slope gradients of 95 percent. They produced an average of 3.6 tons per acre per year, 5 times that produced by the non-rejuvenated, south-facing front-country slopes, which have 55 percent gradients. In contrast, the front-country north slopes, rejuvenated and non-rejuvenated, produced alike; both had gradients near the angle of repose for this type of material and vegetation condition--60 to 70 percent. In general, south slopes produced from 1-1/2 to 10 times as much debris as north slopes.

The drier non-rejuvenated back-country sites, even though they had poor cover density, produced only half as much debris as the non-rejuvenated front-country sites with similar slope gradients and aspects.

Where slope and soil conditions are similar, increased cover density apparently reduced debris movement, as shown by comparison of the Singing Springs north and south slopes. Clearly too, on south rejuvenated sites with steep slopes, old cover was not enough to prevent large amounts of debris production. These south rejuvenated slopes were the principal sources of debris.

At least 0.2 tons of debris per acre per year were recorded on all sites. Slopes with gradients of 70 percent or less had low average annual sediment yields--at most 0.72 tons per acre per year, whereas slopes of 90 percent yielded more than 3 tons per acre annually. Thus, slope alone may be an index to the principal sources of debris in these mountains under unburned cover conditions.

3/ Erosion chutes are caused by the concentrated movement of soil and rock down segments of steep slopes during both wet and dry periods. Reference. Blackwelder, Eliot, "The Process of Mountain Sculpture by Rolling Debris." Journal Geomorphology 5(4):324-328, 1942.

Annual debris production varied widely between sites and between years (tables 2, 3, 4). Debris production from front-country south rejuvenated slopes ranged from 2.15 to 5.66 tons per acre per year, varying by a factor of 2.6. At other sites the year-to-year debris production varied by a factor of only 1.5 to 2. Maximum year-to-year variation was at a south rejuvenated slope; debris production ranged from 1.1 to 15 tons per acre at one site, thus varying by a factor of 14. Such variations indicate that the mean of debris production for this slope might be considerably in error. This is true for the years of study; other years could bring other differences in the mean.

THE ANNUAL CYCLE OF DEBRIS PRODUCTION

On front-country south rejuvenated slopes debris production showed a distinct seasonal pattern (fig. 3). Typically, at the end of the winter rainy period, debris production was low because moisture gave cohesion to the soil. As the surface soil dried, debris started sliding and persistently high rates of sediment production were maintained. A breeze that shook the brush was enough to start a minor slide; the passage of a deer, even the vibrations of an airplane, sent rocks hurling downslope and small material followed. The fall rain ended this debris sliding, as water again gave cohesion to the soil. However, the first rain on these steep slopes sometimes loosened a few large rocks which came tumbling down as the final curtain of the dry season.

Wet-Season Debris Production

The wet-season debris production was controlled by the amount and intensity of the rainfall and modified by soil moisture. The first rain went to soil moisture storage; as this was satisfied at each point, quick seepage and local surface runoff combined to surge down minor channels, cutting through the debris left from the dry season flows. As the wet season progressed, soil-moisture storage was satisfied in larger and larger areas so that greater and greater surges of runoff and entrained debris flushed into the troughs during rainstorms.

Even under wet conditions on the worst sites--steep rocky rejuvenated slopes--rainfall intensities in excess of 0.25 inches per hour were needed to produce significant surges of debris. Thus, debris movement was frequently low for storms with large amounts of total rainfall. On the other hand, short bursts of high intensity rain sometimes caused high debris movement even when the total rain was low. This occurred in the December 9-10, 1954 storm when the total storm rainfall was only 0.87 inches. This storm produced near record debris discharges at the south rejuvenated sites, where one-half ton per acre was measured for this single small storm.

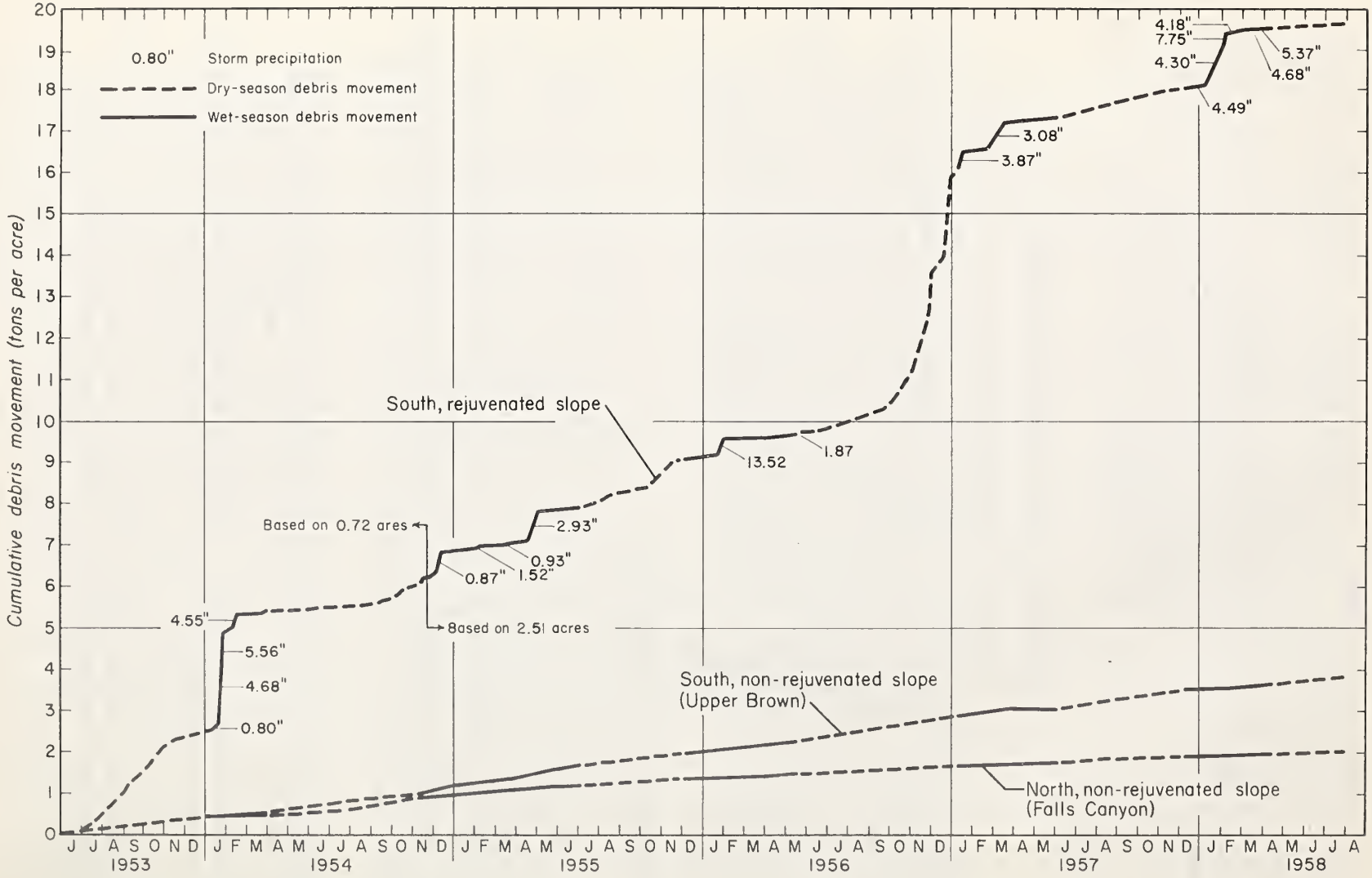

Figure 3.--Wet and dry-season debris production from "front country" sites of the San Gabriel Mountains, California, 1953-1958.

Some high surges of debris remained unexplained. Did a key rock or plant give way? Did a deer try a new trail? In some areas such as our study sites, "accidental happenings" were sometimes a large contributor to a single debris production.

In the first 4 years of the study, rainfall was generally deficient, averaging 77 percent of normal. In the last year of study, 1957-58, the fall was 143 percent of normal. However, rainfall was generally low in intensity, and only at the Singing Springs site was there an increase in wet-season debris movement in this last year.

Dry-Season Debris Production

Dry-season debris production exceeded wet-season movement on most of the sites during the period of study (table 1). Dry-season movement averaged about 1.2 times the wet on the south rejuvenated sites. Thus, a large part of the debris movement from side slopes in these mountains is seemingly independent of runoff.

The dry seasons of these years of study may be abnormal. The June to December temperature were above normal in each of the years of study, averaging nearly 2°F above normal. However, the number of summer months with less than 1-inch of rainfall (at Pasadena) was about normal, averaging 6 months as compared with $6\frac{1}{2}$ for the 55-year average. For most, but not all sites, the dry-season movement varied with the temperature excess. Thus, under normal conditions dry-season debris production may be somewhat less dominant than was indicated in this period of study.

TYPES OF DEBRIS

Not all of the debris moving into the troughs was soil in the usual definition; much was rock and organic matter. The types of materials, representing samples of rock for the period June 1955 to 1956 and organic matter from the start of the study to January 1957, are summarized below:

Study site	Percent rock >1-1/2 in. dia.	Percent organic matter
North rejuvenated	78	8
South rejuvenated	9	7
Upper Brown	3	36
Falls	2	29
Singing Springs North	0	24
Singing Springs South	0	17

The highest production of rock came from the rejuvenated sites. On the south-facing sites, rejuvenation probably is cutting into the slopes faster than the diorite rock weathers into soil. On the north-facing sites, the higher percent of rock reflects a loose colluvial soil with a high rock content.

On non-rejuvenated sites, more organic matter and less rock moved down slope. Organic content was highest, 36 percent, at Upper Brown, a front-country non-rejuvenated site. Most of the organic material consisted of leaves and twigs which are slow to decay in this dry climate.

DISCUSSION

This study covered a very brief period in geologic time, yet the measurements undoubtedly bring out the primary sediment sources from these mountains. The movement was downslope to the channels only. Over short periods this movement does not necessarily correlate with sediment discharge into reservoirs or other improvements. No significant amounts of sediment moved into debris basins from unburned watersheds during this period of study. Yet the debris moved downslope; it remains in the channels--a constant threat to downstream areas.

SUMMARY AND CONCLUSIONS

To reduce the amount of debris coming from the mountain front above Los Angeles and its neighboring cities will demand the combined efforts of many organizations. A major question is: Where does this debris come from and how does it move? This study has provided some of the answers.

The primary sources of debris from areas of unburned brush cover proved to be the south rejuvenated slopes along the mountain front--an average of 3.56 tons per acre per year moved down those slopes. Dry-season debris movement exceeded the wet-season movement on all of the front-country slopes. When dry, the non-cohesive soils on steep slopes started sliding with every breeze or passage of a deer. Wet-season movement equalled or exceeded the dry-season movement on the less steep back-country slopes.

The 5-year study period encompasses four rather dry years in which rainfall averaged only 77 percent of normal and one wet year, with rainfall 143 percent of normal.

To stabilize these mountain slopes and prevent more debris from moving into channels is the challenge. Economic and effective methods need to be developed, tested, and applied. Otherwise, the mountain walls along the Los Angeles front will continue to "come tumbling down."

Table 1.--Summary of study site characteristics and average seasonal debris production

Site	Site characteristics					Years of data	Average debris production		
	Slope condition (Geological)	Aspect	Area	Cover density	Average slope		Dry season	Wet season	Annual
			Acres	Percent	Percent		Tons/ac	Tons/ac	Tons/ac
Back Country									
Singing Springs 1	non-rejuvenated	SW	1.30	65	60	5	.10	.20	.30
Singing Springs 2	non-rejuvenated	NE	1.64	85	55	5	.10	.10	.20
Front Country									
Upper Brown	non-rejuvenated	SW	0.68	95	55	5	.42	.30	.72
Falls	non-rejuvenated	NE	1.53	95	60	5	.22	.14	.36
Lower Brown(I&II)	Rejuvenated 1/	NE	6.81	95	70	3-1/2	.22	.15	.37
Lower Brown(III,IV,V)	Rejuvenated	SE	2.51	65	90	2/ 3-1/2 and 5	1.92	1.64	3.56

1/ Rejuvenated slopes are steep slopes flanking rejuvenated streams channels, a result of recent uplift of the fault block forming the San Gabriel Mts.

2/ Data were collected for one segment of this slope of 0.72 acres for 5 years, for the remaining 1.79 acres for 3-1/2 years.

Table 2.--Seasonal debris movements, non-rejuvenated slopes, residual soil

Season From	Season To (inc)	Number of days	Upper Brown Dry season	Upper Brown Wet season	Falls Dry season	Falls Wet season	Singing Springs South Dry season	Singing Springs South Wet season	Singing Springs North Dry season	Singing Springs North Wet season
			Tons per acre		Tons per acre		Tons per acre		Tons per acre	
6/23/53	1/12/54	204	.437		1/ .336		.045		.082	
1/13/54	3/30/54	77		.147		1/ .113		.103		.038
4/1/54	11/9/54	224	.349		1/ .282		.095		.091	
11/10/54	6/7/55	209		.685		.298		.191		.093
6/8/55	11/29/55	174	.345		.165		.079		.097	
11/30/55	5/16/56	169		.316		.118		.079		.076
5/17/56	1/8/57	237	.630		.207		.155		.124	
1/9/57	6/4/57	147		.156		.072		.063		.036
6/5/57	12/4/57	183	.344		.113		.144		.122	
12/5/57	4/15/58	133		.196		.084		.567		.268
Totals			2.105	1.500	1.103	.685	.518	1.003	.516	.511
Tons/Acre/Season			.42	.30	.22	.14	.10	.20	.10	.10
Tons/Acre/Year			.72		.36		.30		.20	

1/ Catches corrected by factor of 0.85 for accelerated section caused by trough construction; section repaired May 22, 1954.

Table 3.--Seasonal debris movement, north rejuvenated slopes, colluvial soil

Season		Number of days	Lower Brown Site I		Lower Brown Site II	
From	To (inc)		Dry season	Wet season	Dry season	Wet season
			Tons per acre		Tons per acre	
11/30/54 1/	6/7/55	189		.208		.135
6/8/55	11/29/55	174	.167		.246	
11/30/55	5/16/56	169		.156		.114
5/17/56	1/8/57	237	.334		.270	
1/9/57	6/4/57	147		.198		.134
6/5/57	12/4/57	183	.159		.159	
12/5/57	4/15/58	133		.080		.161
Totals			.660	.642	.675	.544
Tons/Acre/ Season			.22	.16	.22	.14
Tons/Acre/ Season			.38		.36	

1/ Beginning of wet season was 11/10/54. Estimated movement between 11/10 and 11/30 is not significant.

Table 4.--Seasonal debris movements, south rejuvenated slopes

From	To (inc)	Number of days	Lower Brown Site III Dry season	Lower Brown Site III Wet season	Lower Brown Site IV Dry season	Lower Brown Site IV Wet season	Lower Brown Site V Dry season	Lower Brown Site V Wet season	Lower Brown Site III, IV, V Dry season	Lower Brown Site III, IV, V Wet season	Lower Brown Site III, IV, V Yearly Totals
			Tons per acre		Tons per acre		Tons per acre		Tons per acre		
6/23/53	1/12/54	204	2.474						2/ 2.474		
1/13/54	3/30/54	77		2.849						2/ 2/849	5.323
4/1/54	11/9/54	224	.739						2/ 0.739		
11/10/54	6/7/55	209		2.970		1/ 1.220		1/ 1.032		1.697	2.436
6/8/55	11/29/55	174	1.584		1.115		1.003		1.235		
11/30/55	5/16/56	169		.495		1.309		.132		0.916	2.151
5/17/56	1/8/57	237	.820		3.781		14.492		4.384		
1/9/57	6/4/57	147		1.985		1.073		.618		1.273	5.657
6/5/57	12/4/57	183	.487		1.047		0.176		.769		
12/5/57	4/15/58	133		3.032		.966		0.125		1.445	2.214
Total			6.104	11.331	5.943	4.568	15.671	1.907	9.601	8.180	17.781
Tons/Acre/ Season			1.22	2.27	1.98	1.14	5.22	.48	1.92	1.64	
Tons/Acre/ Year			3.49		3.12		5.70		3.56		

1/ Data for Sites IV and V began 11/22/54, or 12 days less than shown. Estimated amount of movement during this period is not significant.

2/ On basis of Lower Brown III only.